FAARFIELD METHOD OF RIGID PAVEMENT DESIGN

FAA Pavement Design

Based on

FAA -AC 150/5320-6E, Airport Pavement Design and Evaluation

FAA Pavement Design

AC 150/5320-6E, Airport Pavement Design and Evaluation

- Completely revised in 2008
- New design methodologies for Rigid and Flexible pavements
- Software dependent design procedures
- Addresses modern airplane parameters

Chapter 3
Pavement Design

Chapter 3 - Pavement Design

- Covers standard pavement design procedures for both flexible and rigid pavement
- Applies to pavement designed for airplanes with gross weights exceeding 30,000 lbs
- Design procedure requires the use of computer program, i.e. FAARFIELD

Chapter 3 - Pavement Design

- Flexible Pavement Design based on **Layered Elastic Design** procedure
    - US Corp of Engineers CBR Method no longer used
- Rigid Pavement Design based on **3-Dimensional Finite Element** model
    - Westergaard design procedure no longer used.

Chapter 3 - Pavement Design

Traffic Models

- New procedures require that **ALL** anticipated traffic be included in the traffic model.
- Concept of "**design aircraft" is no longer used**
- **Cumulative Damage Factor (CDF)** replaces need for design aircraft procedure.

Traffic Model - **Cumulative Damage Factor**

- Sums Damage From ***Each*** Aircraft
  - Based upon its **unique pavement loading characteristics** and
  - **Location of the main gear** from centerline

- **DOES NOT** use the "design aircraft" method of condensing all aircraft into one design model

Chapter 3 - Pavement Design

Traffic Model - Cumulative Damage Factor

- Sums Damage From ***Each*** Aircraft - Not From "Design Aircraft"

$$\text{CDF} = \frac{\text{number of applied load repetitions}}{\text{number of allowable repetitions to failure}}$$

- When CDF = 1, Design Life is Exhausted

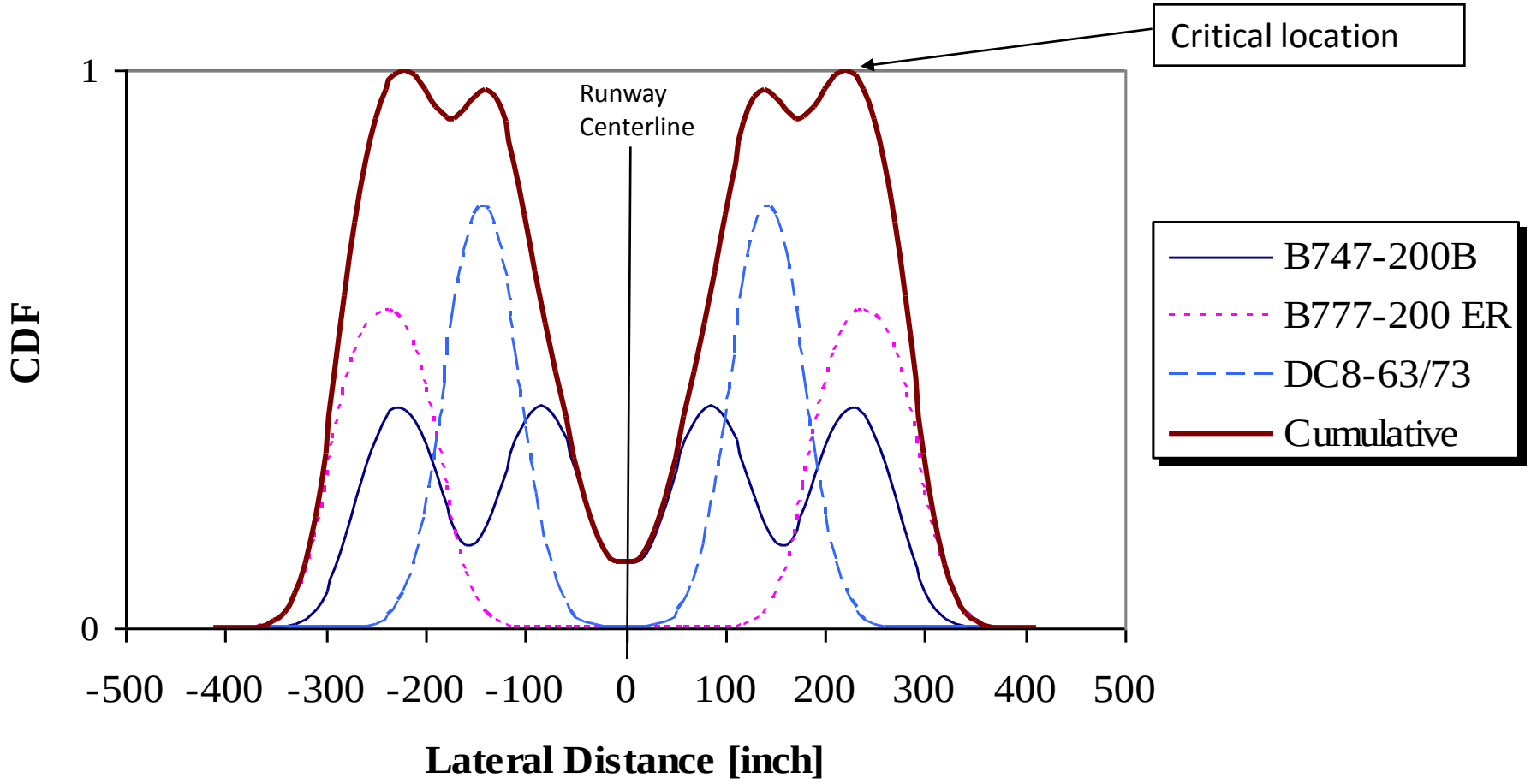
Chapter 3 - Pavement Design

Traffic Model - Cumulative Damage Factor

- CDF is Calculated for each 10 inch wide strip over a total 820 inch width.
- **Gear location** and **wander** considered for each aircraft
- Sum the damage for each strip

- Must Input Traffic Mix, NOT "Design Aircraft"

Traffic Model - Cumulative Damage Factor

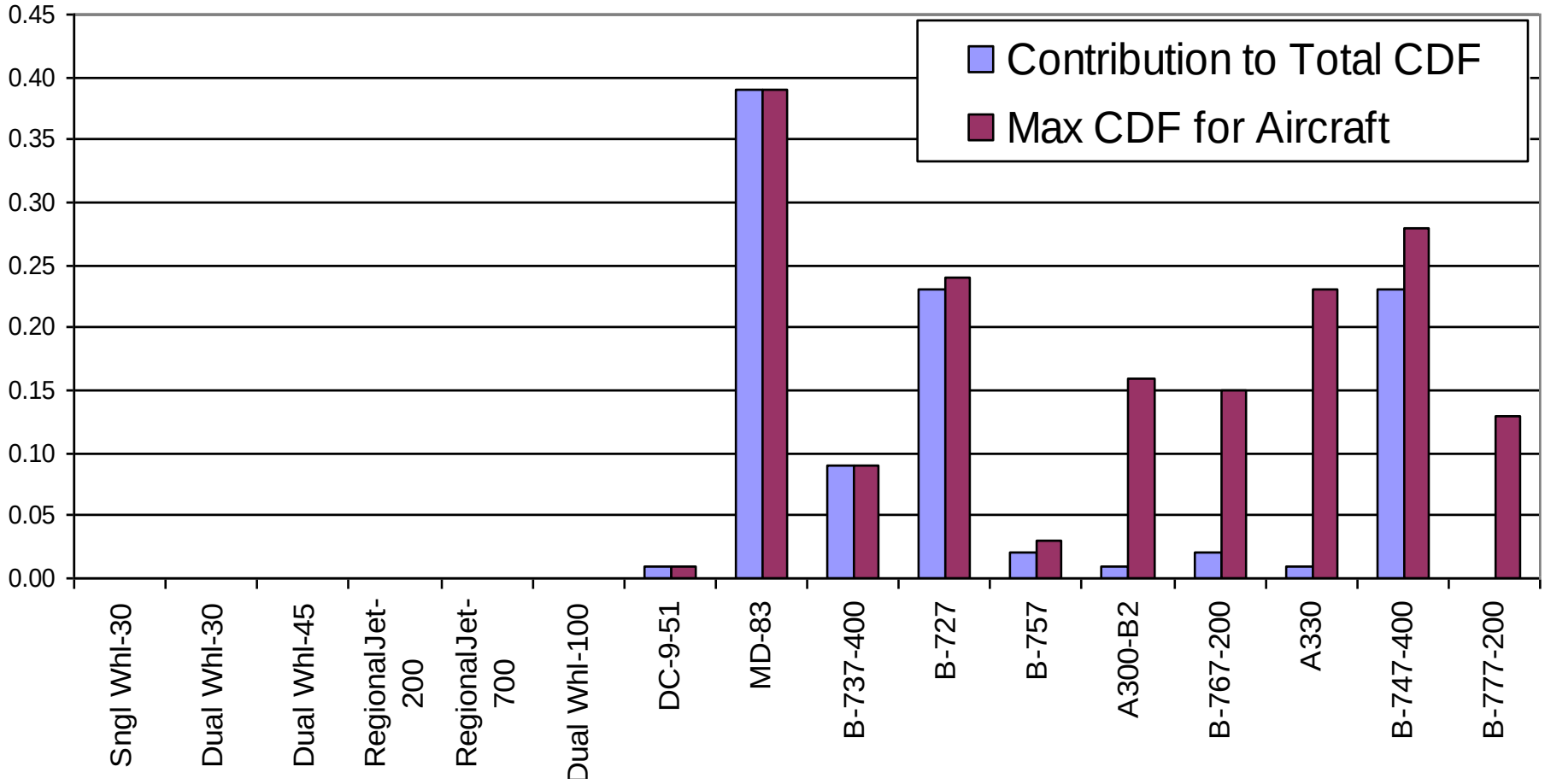


Sample Aircraft Traffic Mix CDF Contribution

Aircraft Name	Gross Weight	Annual Departures	CDF Contribution	CDF Max For Aircraft
Sngl Whl-30	30,000	1,200	0.00	0.00
Dual Whl-30	30,000	1,200	0.00	0.00
Dual Whl-45	45,000	1,200	0.00	0.00
RegionalJet-200	47,450	1,200	0.00	0.00
RegionalJet-700	72,500	1,200	0.00	0.00
Dual Whl-100	100,000	1,200	0.00	0.00
DC-9-51	122,000	1,200	0.01	0.01
MD-83	161,000	1,200	0.39	0.39
B-737-400	150,500	1,200	0.09	0.09
B-727	172,000	1,200	0.23	0.24
B-757	250,000	1,200	0.02	0.03
A300-B2	304,000	1,200	0.01	0.16
B-767-200	335,000	1,200	0.02	0.15
A330	469,000	100	0.01	0.23
B-747-400	873,000	100	0.23	0.28
B-777-200	537,000	500	0.00	0.13

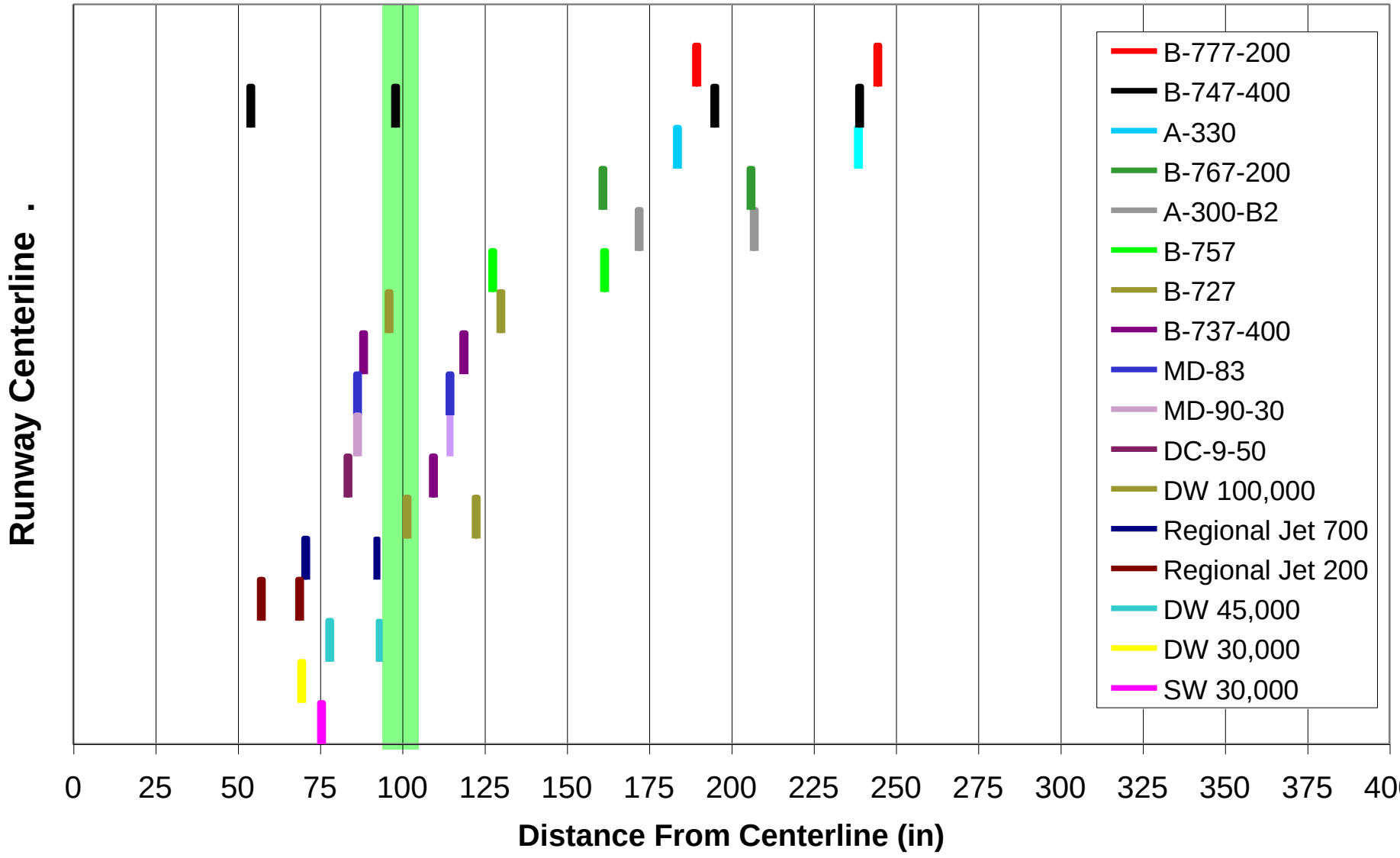
Condition specific and not a general representation of noted aircraft

Sample Aircraft Traffic Mix CDF Contribution

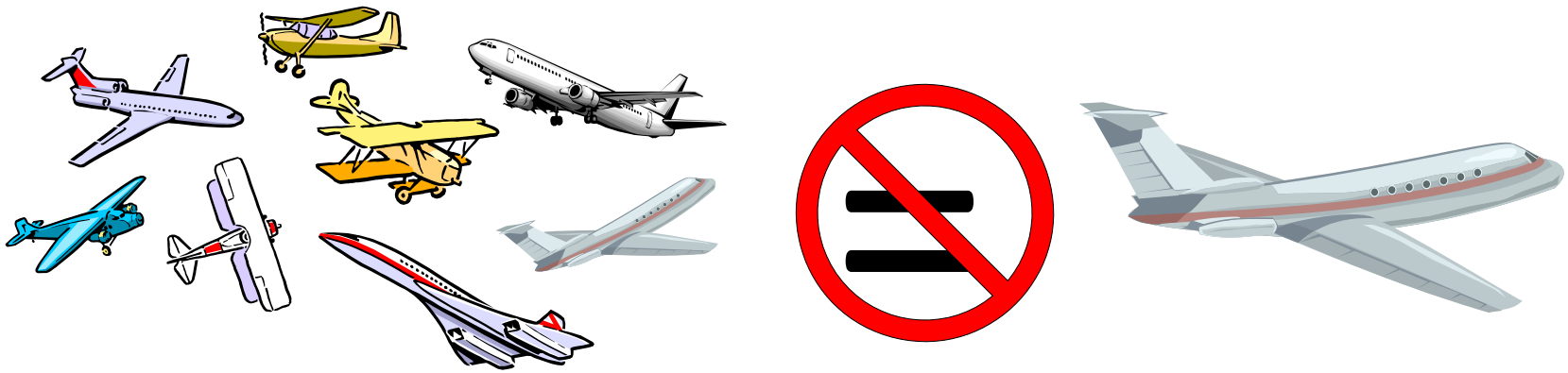


Condition specific and not a general representation of noted aircraft

Large Aircraft Traffic Mix Gear Locations



Remember



Must use the entire traffic mixture

No more “Design Aircraft”

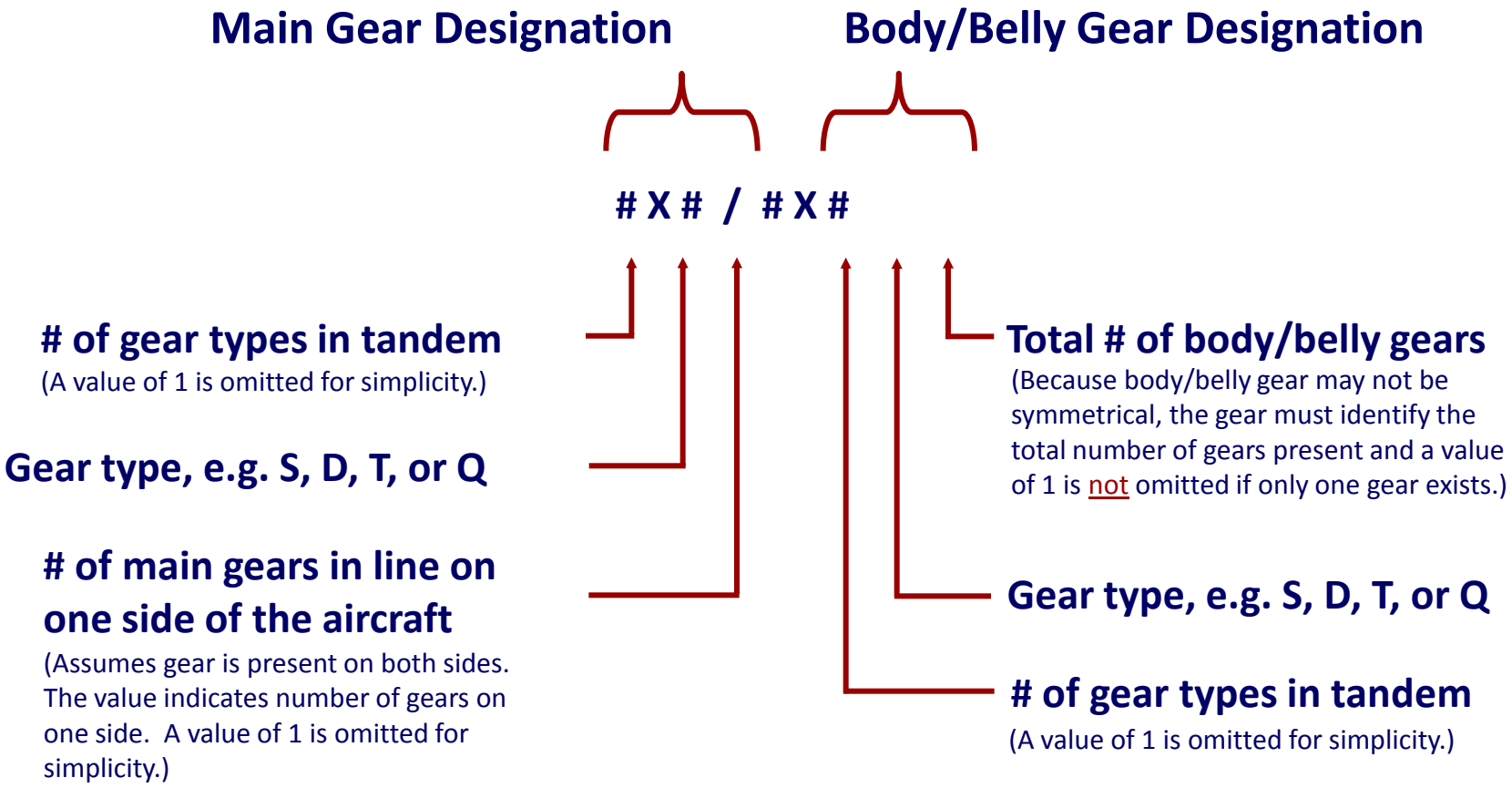
Comparisons between new and previous design procedures using “design aircraft” for the traffic model will result in significant differences

Chapter 3 - Pavement Design

Traffic Model – Airplane Characteristics

- FAARFIELD program currently provides 198 different aircraft models
- Each model is unique with respect to gross load, load distribution, wheel spacing, and tire pressure
- Gear types identified in accordance with FAA Order 5300.7
  - Eliminates “widebody” terminology

Traffic Model – Gear Naming Convention


Main Gear Designation
Body/Belly Gear Designation
X # / # X
of gear types in tandem
(A value of 1 is omitted for simplicity.)
Gear type, e.g. S, D, T, or Q
# of main gears in line on one side of the aircraft
(Assumes gear is present on both sides. The value indicates number of gears on one side. A value of 1 is omitted for simplicity.)
Total # of body/belly gears
(Because body/belly gear may not be symmetrical, the gear must identify the total number of gears present and a value of 1 is not omitted if only one gear exists.)
Gear type, e.g. S, D, T, or Q
# of gear types in tandem
(A value of 1 is omitted for simplicity.)

Traffic Model – Gear Naming Convention

Single **S**

Dual **D**

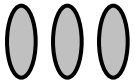
Triple **T**

Quadruple **Q**

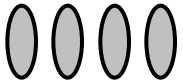
Traffic Model – Gear Naming Convention

Single
S

Dual
D

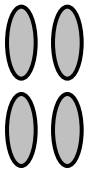


Triple
T

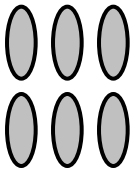


Quadruple
Q

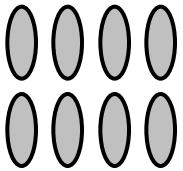
2 Singles in Tandem
2S



2 Duals in Tandem
2D

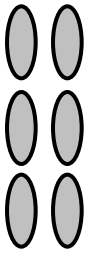


2 Triples in Tandem
2T

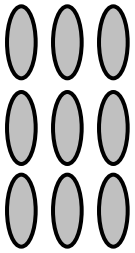


2 Quadruples in Tandem
2Q

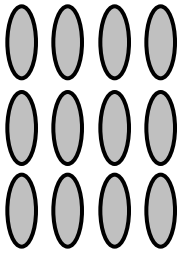
3 Singles in Tandem
3S



3 Duals in Tandem
3D

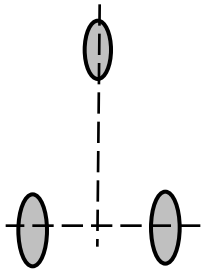


3 Triples in Tandem
3T

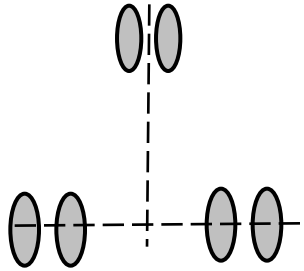


3 Quadruples in Tandem
3Q

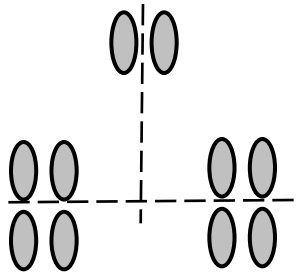
Chapter 3 - Pavement Design -- Examples



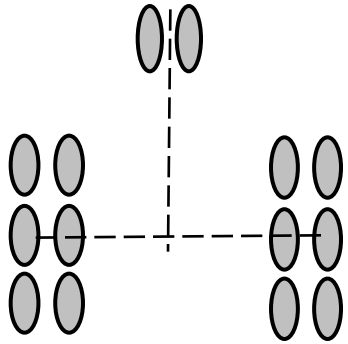
S
Single Wheel



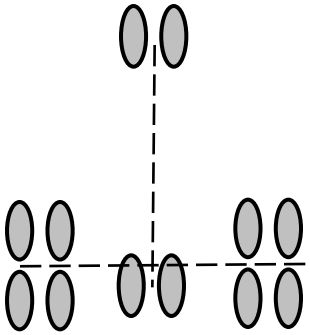
D
Dual Wheel



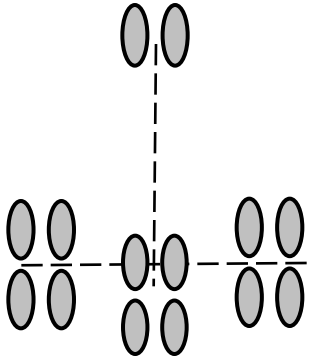
2D
Dual Tandem



3D
B777

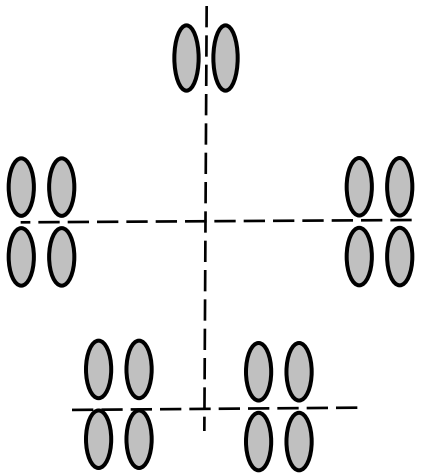


2D/D1
DC-10

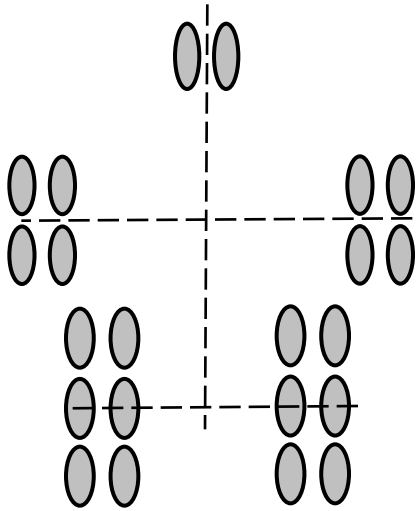


2D/2D1
A340-600

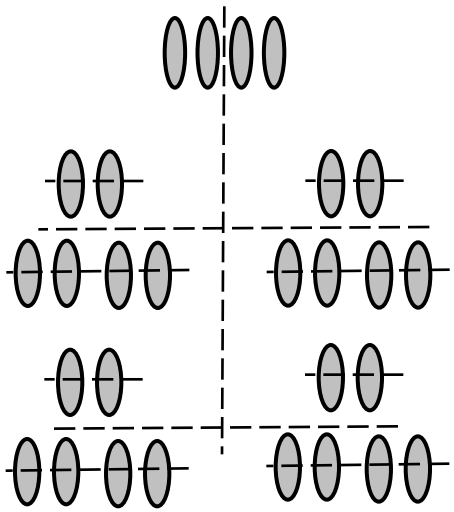
Chapter 3 - Pavement Design -- Examples



2D/2D2
B747



2D/3D2
A380



C5
Lockheed C5

Chapter 3 - Pavement Design

Traffic Model – Pass to Coverage (P/C) Ratio

- Lateral movement is known as airplane wander and is modeled by statistically normal distribution.
  - Standard Deviation = 30.435 inches (773 mm)
- (P/C) -The ratio of the number of trips (or passes) along the pavement for a specific point on the pavement to receive one full-load application.
- -6E utilizes new procedure for determining P/C

Traffic Model – Pass to Coverage (P/C) Ratio

- Rigid Pavement

  One Coverage = One full stress application to the bottom of the PCC layer

- Flexible Pavement

  One Coverage = One repetition of maximum strain at the top of the subgrade layer

Chapter 3 - Pavement Design

Traffic Model – Pass to Coverage (P/C) Ratio

- -6E (FAARFIELD) uses the concept of “Effective Tire Width”
- Rigid Pavement – Effective width is defined at the surface of the pavement (equal to tire contact patch)

  (same as previous P/C procedures)

- Flexible Pavement – Effective width is defined at the surface of the subgrade layer

Chapter 3 - Pavement Design – Frost Design

FROST DESIGN - 3 options

- Complete Frost Protection
  - Remove frost susceptible materials to below frost depth
- Limited Frost Protection
  - Remove frost-susceptible material to 65% frost depth
  - Limits frost heave to tolerable level
- Reduced Subgrade Strength
  - Reduce subgrade support value
  - Design adequate load carrying capacity for weakened condition

Chapter 3 - Pavement Design – Typical Sections

- Airport pavements are generally constructed in uniform, full width sections

- Variable sections are permitted on runway pavements

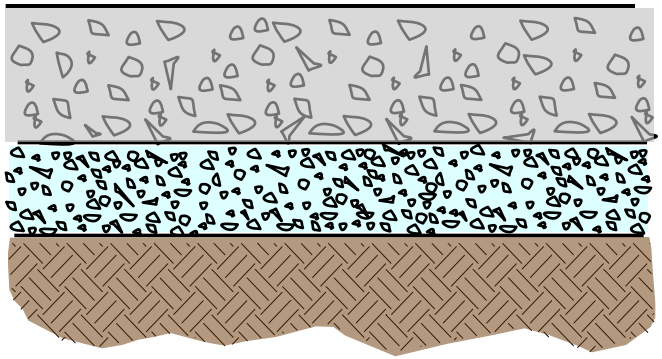
  Designer should consider:

  Practical feasibility – complex construction operations

  Economical feasibility – cost of complex construction

Chapter 3 Section 3 – Rigid Pavement Design

Typical Rigid Pavement



Portland Cement Concrete (PCC)

Subbase Course **

Subgrade

** Stabilization required when airplanes exceeding 100,000 lbs are in the traffic mixture.

Chapter 3 Section 3 – Rigid Pavement Design

Surface	SUBBASE	SUBGRADE
P-501	P-154	P-152
	P-208	P-155*
	P-209	P-157*
	P-211	
	P-301	
	P-304*	
	P-306*	
	P-401*	
	P-403*	
	Rubblized PCC	

* Chemically Stabilized Materials

3-Dimensional Finite Element Design

- NEW procedure
- Rigid design uses 3-D finite element method (3D-FEM) for direct calculation of stress at the edge of a concrete slab.
- Predictor of pavement life

  Maximum Stress at pavement edge

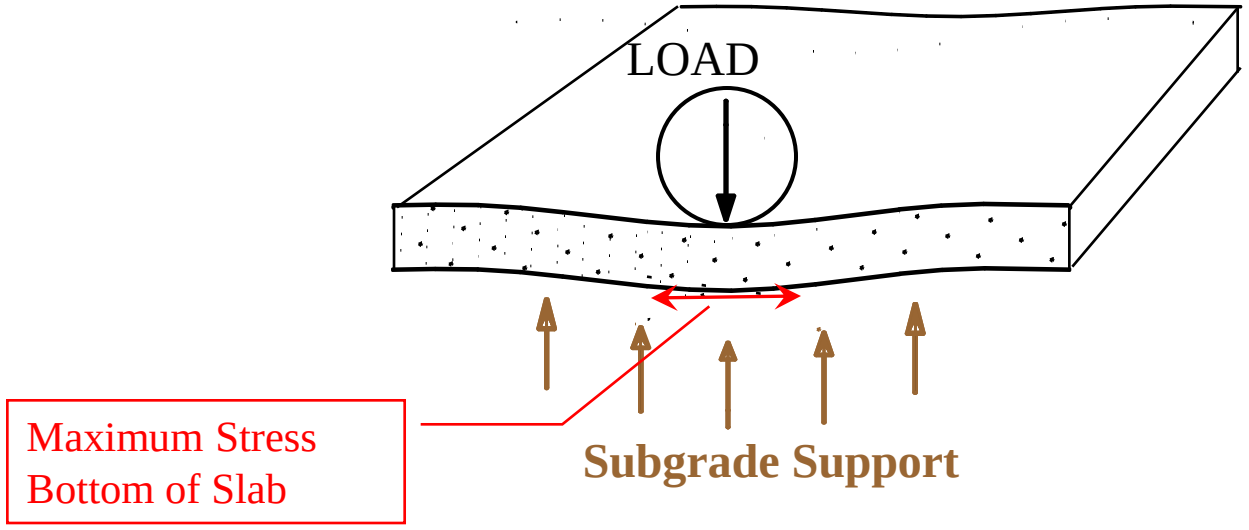
  Assumed position – bottom at slab edge

Chapter 3 Section 3 – Rigid Pavement Design

CRITICAL LOAD CONDITION ASSUMPTIONS

Maximum stress at pavement edge

25% Load Transfer to adjacent slab



Chapter 3 Section 3 – Rigid Pavement Design

Pavement Structural Design Life

Default "design life" is for 20 years

Structural design life indicates pavement performance in terms of allowable load repetitions before "First Crack" i.e. SCI = 80.

Structural life is determined based upon annual departures multiplied by 20 (yrs). This value may or may not correlate with calendar years depending upon actual pavement use.

Pavement performance in terms of surface condition and other distresses which might affect the use of the pavement by airplanes is not directly reflected in the structural design life.

REQUIRED INPUT VARIABLES

- Subgrade support conditions
  - k-value or Modulus
- Material properties of each layer
  - Modulus for all layers (flexural strength for PCC)
  - Thickness for all layers except surface PCC
  - Poisson's Ratio – fixed in FAARFIELD
- Traffic
  - Frequency of load application
  - Airplane characteristics
    - Wheel load, wheel locations, & tire pressure

Subgrade Characteristics

- Subgrade assumed to have infinite thickness
- FAARFIELD accepts Resilient Modulus E_{SG} or k-value (only necessary to enter one value)

  Converts k-value to modulus

$$E_{SG} = 26k^{1.284}$$

E_{SG} = Resilient modulus of subgrade, in psi

k = Foundation modulus of the subgrade, in pci

AASHTO T 222, Nonrepetitive Static Plate Load Test of Soils and Flexible Pavement Components, for Use in Evaluation and Design of Airport and Highway Pavements

Subgrade Characteristics

k-value can be estimated from CBR value

$$k = \left[\frac{1500 \times CBR}{26}\right]^{0.7788}$$

k = Foundation modulus of the subgrade, in pci

Subbase Layer Characteristics

- Minimum material requirements
  - P-154, P-208, P-209, P-211, P-301, P-304, P-306, P-401, P-403, & rubblized PCC
- Up to three subbase layers allowed in FAARFIELD
- Aggregate layer modulus dependent on thickness
  - Modulus calculated by FAARFIELD based on thickness
- 4 inch minimum thickness requirement

Portland Cement Concrete Layer Characteristics

- Minimum material requirements
  - P-501
- Flexural Strength as design variable
  - FAA recommends 600 – 700 psi for design purposes
  - FAARFIELD will allow 500 – 800 psi
  - ASTM C 78 Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)
  - Modulus fixed at 4,000,000 psi
- 6 Inch minimum thickness requirements
- Thickness rounded to the nearest 0.5 inch

Chapter 3 Section 3 – Rigid Pavement Design

Design Flexural Strength versus P-501 Specification

- Design Strength can be 5% greater than P-501 28-day strength
- e.g. P-501 = 650 psi then design at 680 psi
- Factors to Consider:
  - Capability of the industry in a particular area to produce desired strength
  - Flexural strength vs. cement content data from prior projects at the airport
  - Need to avoid high cement contents, which can affect concrete durability
  - Whether early opening requirements necessitate using a lower strength than 28-day

Chapter 3 Section 3 – Rigid Pavement Design

Traffic Input for Rigid Pavement Design

- Airplane characteristics
  - 198 Airplane models currently available in FAARFIELD
  - Wheel load – determined automatically based on gross weight
  - wheel locations – Internal to FAARFIELD aircraft library
  - tire pressure – Internal to FAARFIELD aircraft library
- Frequency of load application
  - Entered as annual departures
    - Arrival traffic ignored
    - User determines percent of total airport volume

Chapter 3 Section 3 – Rigid Pavement Design

Rigid Pavement Joint Types and Details

- 5 joint types provided in 5320-6E
  - Isolation Joints
    - Type A – Thickened Edge
  - Contraction Joints
    - Type B – Hinged
    - Type C – Doweled
    - Type D – Dummy
  - Construction Joints
    - Type E – Doweled